Effect of Replacement of Cement by Different Pozzolanic Materials on Heat of Hydration and Setting Time of Concrete

Mallikarjun Ganjigatti[1], Kashinath B. R.[2], K. B. Prakash[3]

[1]P.G. Student, M. Tech. (Structural Engineering)
[2]Assistant Professor, Civil Engineering Department
[3]Principal, Civil Engineering Department, Government Engineering College, Devagiri, HAVERI – 581 110, Karnataka, India

Abstract— *The paper aims to focus on the possibility of using industrial by products like SF, GGBS, FA and MK. The utilization of pozzolans is well accepted because of several improvements possible in the concrete composites. The present study reports the results of experimental study conducted to evaluate Setting Time, HOH and Compression Strength of Concrete, by partially replacing cement by various percentages of silica fume (SF), ground granulated blast furnace slag (GGBS), fly ash (FA) and metakaolin (MK) (5%, 10%, 15%, & 20%). The Heat of Hydration (HOH) and Compression Strength test are done for M30 grade concrete. The effort is made towards a specific understanding of efficiency of pozzolans in concrete considering the percentage of replacement and combinations of pozzolans. The pozzolans replacement as cementitious material is characterised by high compressive strength, low heat of hydration and increased initial and final setting time of concrete.*

Keywords— Concrete***, GGBFS, Fly Ash, Silica Fume, Metakaolin, Heat of Hydration, Setting time, Shear test.***

I. INTRODUCTION

Concrete plays a very important role in the present growing construction industry. Cement and other additives are mixed to form concrete. Cement industry has huge effects on environment, usage of energy and economy. The materials may fully or partially replace the OPC which satisfy the necessities of durability and strength characteristics. Among several substitute materials, such as FA, GGBFS, MK, SF, RHA, etc., are some of industrial waste have been well known by the Industry. So, cement replacing by industrial waste or by products is very beneficial with regard to economy, durability, strength and other co-friendly benefits. These materials are now termed as complimentary cementitious materials (CCM). Badogiannis.E et. al. stated MK has a very progressive influence on the cement strength after 2 days and precisely at 28 and 180 days. Folagbade and Samuel Olufemi studied standard consistency, setting times, heat of hydration and compressive strength of cement combination pastes comprising of ordinary portland cement, SF, FA and MK. The results display that FA would decrease the heat of hydration, increase the setting times and add to the later age strength improvement, silica fume and metakaolin because of their higher fineness would increase the HOH, decrease the setting times and contribute to both early and later age strength development. Muhit.B et. al. studied replacement of cement by Silica Fume and Fly Ash on Water Permeability and Strength of High Performance Concrete and concluded that 20% of Fly Ash and10% of Silica Fume displayed the minimum water penetration depth of 15mm and11mmrespectively. 10% Fly ash and 7.5% Silica fume replacement gave maximum split tensile strength, maximum compressive strength in addition to maximum flexural tensile strength. Supplementary cementitious materials (SCM) such as FA, GGBS, MK, and SF are being used in concrete due to environmental, cost-effective, and concrete quality-related concerns. Concrete practice have shown that the performance of concrete including SCM, such as setting time, heat of hydration and compressive strength development, prominently depends on the sources, characteristics, replacement levels, combinations of SCM and weather conditions. Concrete containing SCM often displays slow hydration that is associated with delayed setting and less early age strength. Its effect is more as the level of SCM replacement is increased.

In this paper the experimental work is carried out to study the effect of replacement of cement by pozzolanic materials on heat of hydration and setting time of concrete. For the study, Pozzolanic materials such as FA, SF, MK and GGBFS are used. The cement is replaced by these pozzolans in various percentage levels such as 5%, 10%, 15% and 20%. The ternary blends such as (FA+SF), (FA+GGBFS) and (FA+MK) are also experimented.

The effect of replacement levels of selected pozzolans in concrete are studied by conducting tests on compressive strength, heat of hydration and setting time of cement. The work is carried out on M30 grade of concrete.

II. TESTING PROGRAMME

In the present study various tests on material such as cement, fine aggregate, coarse aggregate and pozzolanic materials were performed as per the Indian Standards.

2.1 Materials Used

2.1.1 Cement: In this experimental work, OPC of 43 grade (conforming to IS: 8112-1989) was used. The properties of cement are tabulated in Table 1.

TABLE 1: PROPERTIES OF CEMENT

Sl. No	Property	Value
1	Specific Gravity	3.15
2	Fineness	4%
3	Standard Consistency	32%
4	Initial Setting Time	45 min
5	Final Setting Time	345 min

2.1.2 Fine Aggregate: Naturally available river sand (confirming to zone II of IS: 383-1970) was used for this experimental work. The specific gravity of the fine aggregate was found to be 2.64.

2.1.3 Coarse Aggregate: Locally available crushed aggregates confirming to IS: 383–1970 is used in this project work of size 20mm below. The specific gravity of coarse aggregate was found to be 2.66.

2.1.4 Water: Water used in this experimental work has quality of drinking water. It will react with cement and forms paste which binds the concrete ingredients to form a matrix. And it also acts as a lubrication to reach its destiny.

2.1.4 Fly Ash: In this experimental work, FA is from thermal power plant Raichur, India, Confirming to IS 3812(part 1) is used.

2.1.5 Ground granulated blast furnace slag: In this experimental work, Ground granulated blast furnace slag is received from ACC Cement factory, hospet, india, Confirming to IS 3812 (part 1) :2003 was used.

2.1.6 Metakaolin: In this experimental work, Metakaolin from 20micron company, vadodara, Gujarat India is used. It is Confirming to IS 3812(part 1):2003.

2.1.7 Silica fume: In this experimental work, silica fume from 20micron Sai Durga Enterprises, Bangalore, Confirming to IS 3812(part 1):2003 was used.

2.2 PREPARATION OF SPECIMENS

The water quantity, cement, fine aggregate and coarse aggregate required for design mix of M30 were calculated based on the procedure given in IS code method in IS :2009. The final mix ratio was 1:1.48:2.5 with water cement ratio of 0.45. The measurement of materials was done by weight using electronic weighing machine. Water was measured in volume. Concrete was placed in moulds in layers. The cast specimens were removed from moulds after 24 hours and the specimens were kept for water curing. The demoulded specimens are as shown in the Fig 1.

FIG 1 DEMOULDED SPECIMENS WITH DESIGNATION

Calculation of cement and pozzolanic materials for compression strength test heat of hydration and setting time is tabulated in Table 2 and Table 3 below.

TABLE 2
CALCULATION OF CEMENT AND PERCENTAGE REPLACEMENT OF POZZOLANIC MATERIALS FOR 3-CUBES

% replacement	Cement (gms)	FA (gms)	GGBFS (gms)	FA+GGBFS (gms)	MK (gms)	FA+MK (gms)	SF (gms)	FA+MK (gms)
0	4725	0	0	0	0	0	0	0
5	4500	235	235	117.5+117.5	235	117.5+117.5	235	117.5+117.5
10	4252	473	473	236.5+236.5	473	236.5+236.5	473	236.5+236.5
15	4016.2	709	709	354.5+354.5	709	354.5+354.5	709	354.5+354.5
20	3780	945	945	472.5+472.5	945	472.5+472.5	945	472.5+472.5

TABLE 3
CALCULATION OF CEMENT AND PERCENTAGE REPLACEMENT OF POZZOLANIC MATERIALS FOR SETTING TIME

% replacement	Cement (gms)	FA (gms)	GGBFS (gms)	FA+GGBFS (gms)	MK (gms)	FA+MK (gms)	SF (gms)	FA+MK (gms)
0	300	0	0	0	0	0	0	0
5	285	15	15	7.5+7.5	15	7.5+7.5	15	7.5+7.5
10	270	30	30	15+15	30	15+15	30	15+15
15	255	45	45	22.5+22.5	45	22.5+22.5	45	22.5+22.5
20	240	60	60	30+30	60	30+30	60	30+30

2.3 TESTING OF SPECIMENS: For each batch of concrete, 3 cubes of 150mm x 150mm x 150mm size were tested to determine compressive strength of concrete and heat of hydration of concrete by replacing cement with different pozzolanic materials at various replacement levels.

III. RESULTS AND DISCUSSIONS

In this section the results obtained from conducting experiments on concrete specimens are shown in the form of graphs and the results are discussed with respect to the graphs plotted. Fig. 2, Fig. 3, Fig. 4 and Fig. 5 shows the variation of initial setting time, final setting time, heat of hydration and compressive strength of concrete respectively when cement is replaced by FA, GGBFS, MK, SF, (FA+GGBFS), (FA+MK), (FA+SF) in different percentages.

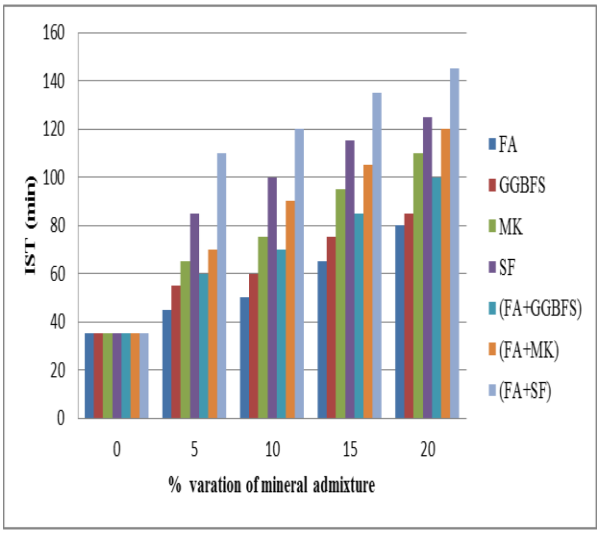

FIG 2 VARIATION OF INITIAL SITTING TIME

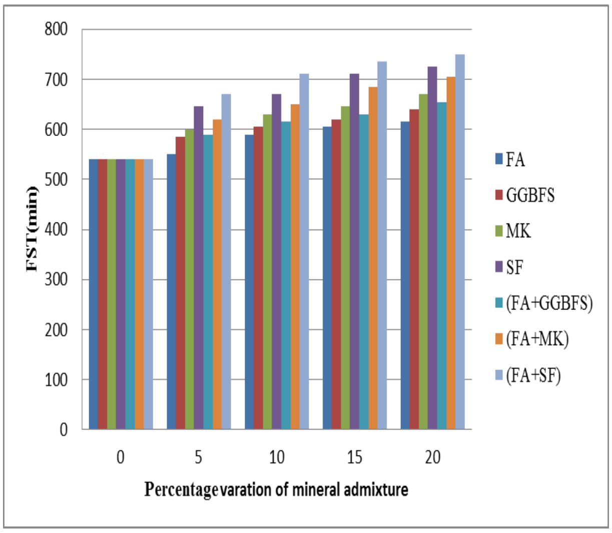

FIG 3 VARIATION OF INITIAL SITTING TIME

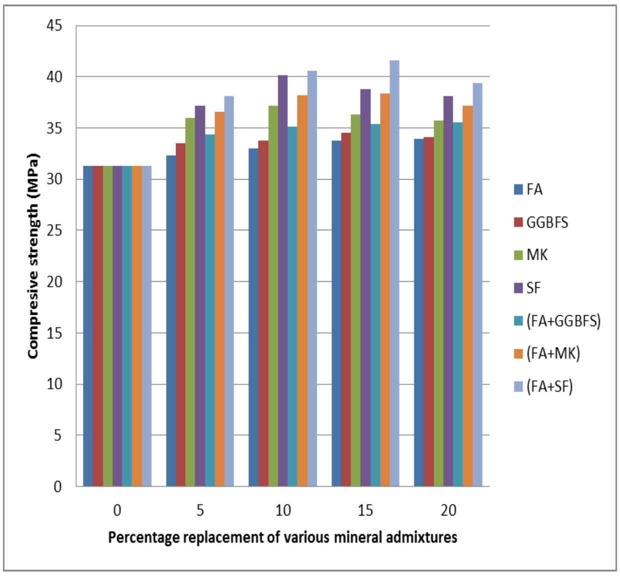

FIG 4 VARIATION OF HEAT OF HYDRATION

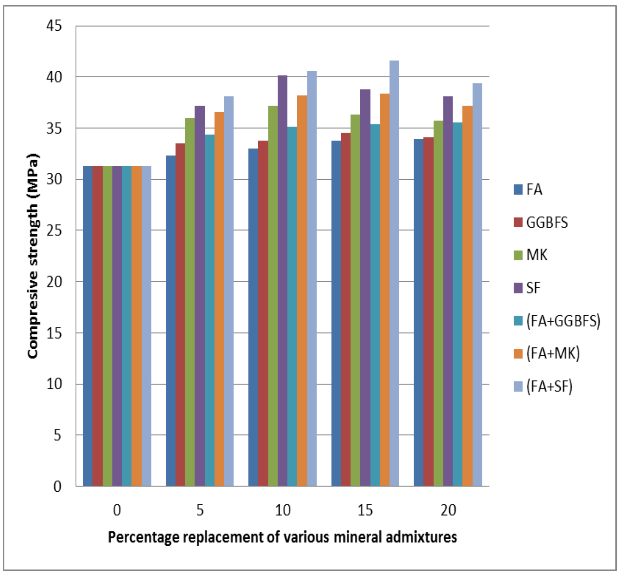

FIG 5 VARIATION OF HEAT OF HYDRATION

IV. OBSERVATIONS

It can be observed from Fig 2 and Fig 3 that the IST and FST of concrete produced by replacing cement by FA or GGBFS or MK or SF or (FA+GGBFS) or (FA+MK) or (FA+SF) goes on increasing as the percentage replacement of cement by these mineral admixtures goes on increasing. Hence it can be stated that the IST and FST for concrete produced by replacing cement by FA is the lowest where as that of concrete produced by replacing cement by (FA+SF) is the highest. In the increasing order of IST and FST the mineral admixtures can be written as FA, GGBFS, (FA+GGBFS), MK, (FA+MK), SF, (FA+SF).

It can be observed from Fig 4 that the HOH of concrete produced by replacing cement by FA or GGBFS or MK or SF or (FA+GGBFS) or (FA+MK) or (FA+SF) goes on decreasing as the percentage replacement of cement by these mineral admixtures goes on increasing. It is also noticed that the HOH for concrete produced by replacing cement by FA is the lowest where as that of concrete produced by replacing cement by (FA+SF) is the highest. In the increasing order of HOH the mineral admixture can be written as FA, GGBFS, (FA+GGBFS), MK, (FA+MK), SF, (FA+SF).

It can be observed from Fig 5 that the higher compressive strength may be obtained by replacing 20% of cement by FA, 15% of cement by GGBFS, 10% of cement by MK, 10% of cement by SF, 20% 0f cement by (FA+GGBFS), 15% of cement by (FA+MK) and 15% of cement by (FA+SF). It is also noticed that the compressive strength of concrete prepared by replacing cement by (FA+SF) yields higher compressive strength as compared to the other mineral admixtures.

V. CONCLUSION

Following conclusion may be drawn based on the experimental study conducted.

1. The workability of concrete produced by replacing cement by FA or (FA+GGBFS) or (FA+SF) increases up to 15%. For concrete produced by replacing cement by GGBFS or MK or SF increases up to 10%. And concrete produced by replacing cement by (FA+MK) increases up to 20%.

2. The IST and FST of concrete produced by replacing cement by FA or GGBFS or MK or SF or (FA+GGBFS) or (FA+MK) or (FA+SF) goes on increasing as the percentage replacement of cement by these mineral admixtures goes on increasing.

3. The IST and FST for concrete produced by replacing cement by FA is the lowest where as that of concrete produced by replacing cement by (FA+SF) is the highest. In the increasing order of IST and FST the mineral admixtures can be written as FA, GGBFS, (FA+GGBFS), MK, (FA+MK), SF, (FA+SF).

4. The HOH of concrete produced by replacing cement byFA or GGBFS or MK or SF or (FA+GGBFS) or (FA+MK) or (FA+SF) goes on decreasing as the percentage replacement of cement by these mineral admixtures goes on increasing.

5. The HOH for concrete produced by replacing cement by FA is the lowest where as that of concrete produced by replacing cement by (FA+SF) is the highest. In the increasing order of HOH the mineral admixture can be written as FA, GGBFS, (FA+GGBFS), MK, (FA+MK), SF, (FA+SF).

6. The higher compressive strength may be obtained by replacing 20% of cement by FA, 15% of cement by GGBFS, 10% of cement by MK, 10% of cement by SF, 20% 0f cement by (FA+GGBFS), 15% of cement by (FA+MK) and 15% of cement by (FA+SF).

7. The compressive strength of concrete prepared by replacing cement by (FA+SF) yields higher compressive strength as compared to the other mineral admixtures.

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